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Level 2 Mineral Resource Assessment Coastal British Columbia

Methodology and Results

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Level 2 Mineral Resource Assessment, Coastal British Columbia - Methodology and Results

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Introduction

In August 2002, the Geological Survey Branch of the Ministry of Energy and Mines was asked by the Ministry of Sustainable Resource Management to undertake a Level 2 Mineral Resource Assessment of the Coast Information Team's (CIT) project area which encompasses approximately 11 million hectares (Figure 1). The primary purpose of this assessment was to provide more detailed information on metallic and industrial mineral resource potential in support of a multi_disciplinary economic gain spatial analysis being done on contract to the CIT. The resource assessment was carried out in early October and final results delivered to the Ministry of Sustainable Resource Management and the CIT at the end of December 2002. This report summarizes the methodology and results of this project. A review of the original Level 1 MRA is also included because the Level 2 MRA is built on the results of the original assessment.

The Coast Information Team

The Coast Information Team (CIT) is an independent, multidisciplinary group established and supported by the Provincial Government of British Columbia, First Nations governments, the forest industry, environmental groups, and communities as part of the implementation of the 2001 BC Coastal Framework Agreement on Conservation and Management of Endangered Old Growth Rainforests. The CIT operates under a joint Memorandum of Understanding between these parties to provide one set of scientific resources for various land use decision-making processes.

The purpose of the CIT is to provide independent information and analyses for the development and implementation of ecosystem-based management in the north and central coastal region of British Columbia, including Haida Gwaii/Queen Charlotte Islands. This information is intended to assist the three sub-regional Land and Resource Management Planning (LRMP) tables and the several First Nations Land Use Planning (LUP) tables in developing practical recommendations to resolve land use and natural resource management issues. For a more complete description of the Coast Information Team and its mandate go to http://www.*citbc*.org/ .

Provincial Mineral Resource Assessment (Level 1)

Background

Early in 1992, the British Columbia Geological Survey Branch of the Ministry of Energy, Mines and Petroleum Resources (later Employment and Investment and now Energy and Mines) launched the Mineral Potential

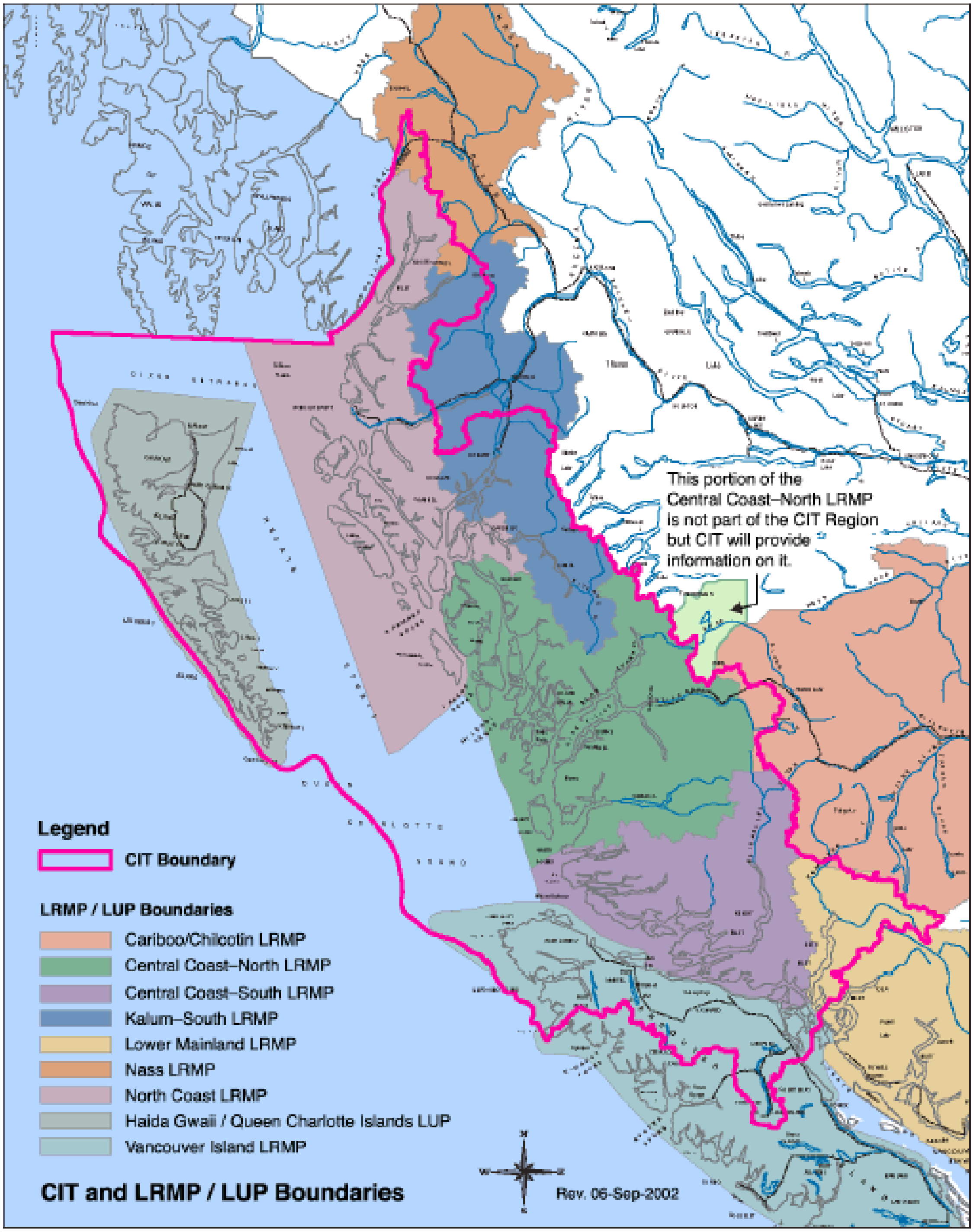

Figure 1. Map showing CIT and LRMP/LUP boundaries

Project to develop the information required by the Commission on Resources and the Environment (CORE) over a 5-year period. The Geological Survey Branch dedicated in excess of 30 geologist years to meet this information requirement. Completion of the assessments in step with the land use planning processes was critical. This earlier assessment is referred to here as a Level 1 MRA.

The first major task of the Mineral Potential Project group was to determine the type of information that would be useful in land use negotiations and develop a methodology which would best produce this information. A two-day workshop involving participants with recent experience in producing and using Mineral Resource Assessments in Canada and around the world determined that the MRA products must have the following characteristics:

- be quantitative rather than qualitative
- provide a ranking of the land base
- have major input from experts from the mining and exploration industries
- produce digital GIS-compatible products
- be readily available.

Quantitative, easily understood results were desired because the LRMP process involved people with a wide range of technical and non-technical backgrounds who had to consider the MRA results in the decision-making process. In addition, quantitative information can be used in subsequent socio-economic analysis. Ranking of the land base was necessary because the Protected Areas Strategy dictated that a target of 12% of the land area in each region would be protected, double the amount protected at that time. A major objective of the Mineral Potential Project was therefore to rank the relative mineral potential of the land base so that planners could easily identify areas with the lowest relative mineral potential during their land use planning.

The mining and exploration industries of BC have built an enormous knowledge base that is not in the public domain. Their involvement and cooperation gave us access to some of this knowledge and also enabled us to familiarize public sector stakeholders with the strengths and limitations of the MRAs. Government dictated production of all information for the land use planning processes in Geographic Information System compatible digital format. Adherence to this policy assured the information was easily incorporated into the analysis systems used by the planners. In addition, storage of the information in digital format provides an opportunity to more easily upgrade the information in the future.

Based on the results of the workshop, a plan for the production of MRAs in BC was developed that was based on the United States Geological Survey's "Three Part Mineral Assessment Methodology" (Singer, 1993). Modifications were made to their procedure to meet the specific requirements of this project. Early in the life of the project, a number of minor adjustments were made to the initial methodology. This methodology has been applied consistently to all assessment regions, so the results from one region may be compared to the results from a neighboring region. Two different techniques are used to assess metallic and industrial mineral commodities due to their very different dependence on infrastructure and markets. A six-step process is used for the metallic resource assessments:

1) compile geology
2) select mineral assessment tracts
3) tabulate discovered resources and construct deposit models

4) employ a team of industry and government experts to estimate the number of undiscovered deposits by deposit type and tract

5) determine quantities of metallic commodities remaining to be discovered using the Mark3B Mineral Resource Assessment Monte Carlo simulator

6) calculate the gross in place value (GIPV) of each tract based on the undiscovered and known commodities it contains.

For industrial mineral assessments the first 4 steps are the same. However, instead of using the Mark3B simulator and associated GIPV, a relative ranking of industrial mineral deposit types was employed. All industrial mineral deposit types were given a relative ranking score from 1 to 100 based on their perceived value and viability. This relative deposit value score (RDVS) was used to determine the importance of each tract with respect to undiscovered deposits. The estimates are then blended with the value of discovered industrial mineral deposits to produce the overall industrial mineral tract assessment ranking.

Deposit Models

Descriptive deposit models were developed as part of the Level 1 MRA for mineral deposits that were known and believed to exist in British Columbia. This work built on the work by the USGS and others (Cox and Singer, 1986) but modified it to establish models that more closely described characteristics expected in BC. Along with the descriptive models, a classification framework was established in which deposit types were ordered according to their genetic characteristics (Lefebure and Ray, 1995, Lefebure et al., 1995 and Lefebure and Höy, 1996).

Descriptive deposit models are essential to the BC mineral resource assessment process. They provide the standardization required to assure that all participants and users understand exactly what is meant when discussing a given deposit type. The deposit examples given in each model help the estimators visualize the deposit type being estimated. The deposit description assists the estimators during the estimation process by identifying characteristic geological, geochemical, geophysical, alteration and weathering features.

MINFILE deposit classification

The MINFILE database of mineral occurrences in the province contains about 12,000 entries. At the start of the Level 1 MRA, this database was in very good shape but did not contain uniform deposit classification information. Consequently, a series of contracts were let to industry consultants to classify the deposits that were listed in MINFILE. The contractors assigned a given deposit up to four possible classifications in order of importance. This classification information is now incorporated into MINFILE and is continually updated as knowledge of the deposits improves. Classification of all known occurrences provided a database that was used for several purposes during the mineral resource assessment. First, the classifications allowed associated resource tonnages to be included in the digital deposit models if they met the qualifying criteria for inclusion in the digital models. Second, knowing the locations of all deposits of a given deposit type in MINFILE was very helpful to estimators during the estimation process.

Geology Compilation

Mineral Resource Assessments rely on accurate, up-to-date geologic information since geology is the primary control for the distribution of mineral resources in the Earth's crust. A major task during the original Level 1 MRA was to compile the geology of the province at a scale of 1:250 000. All available information was examined and reinterpreted using the latest information on the geology of the region. Typically, all available provincial, federal, academic and industry work was compiled and digitized to form the final map product. More than 30 geologist-years were dedicated to this effort. All compilations were produced in GIS compatible digital format and were made available for download and viewing over the Internet (http://www.mapplace.ca). This geological compilation formed the basic framework on which all subsequent MRA analysis was performed.

MRA Tracts

Upon completion of the geological compilation, the province was divided into mineral assessment tracts. These tracts are based on common geologic features and their boundaries correspond to existing geologic boundaries such as faults or significant changes in the age and types of rocks present. Once defined, these tracts become the base unit areas in which the assessments are performed. The original Level 1 MRA resulted in the definition of 794 tracts in the province. The size of tracts can vary significantly but in general were intended for use on a broad regional scale (e.g. 1:250,000). The average size of tracts in the Level 1 assessment is about 100,000 hectares. For each tract, permissive deposit types were determined and an estimate for their existence within the tract in question was made by a panel of experts.

Deposit Model Data Preparation

The two types of input required for the Monte Carlo Mineral Resource Simulator are the experts' estimates of the potential for new discoveries and the digital deposit models describing the grade and tonnage distribution of each deposit type for which the simulator will be used. The digital deposit model contains a list of realistic deposit grades and tonnages for the model types that might be found in the area being assessed. The USGS has constructed many of these models using deposits from around the world. In some cases the parameters of these models were modified to better describe probable grade and tonnage distributions for deposits likely to be found in British Columbia. In most cases this was accomplished by removing very large deposits from the model. New models were required where an adequate model did not exist. In some cases existing USGS models were combined or subdivided to better accommodate the British Columbia situation (Grunsky, 1995).

Known Resources

The final resource assessment value for each tract incorporates both the known and yet to be discovered resources. The known resource values were compiled under a contract as part of the Level 1 MRA project. Each mineral occurrence in the provincial database was researched to see if any resource values had ever been published. All deposits with resource values were tabulated and their deposit types evaluated. These values were incorporated into the digital deposit models that are used as part of the input to the Mark3B simulator. The results of this resource compilation work were subsequently incorporated into the MINFILE database and have been published as Open File 1995-19 (MINFILE Team, 1995). This publication is the source of resource values used in the final calculation of the Level 1 tract assessment score. The resource values were converted to a pseudo-dollar value based on a commodity price list developed for the Level 1 assessment.

Commodity Values

A dollar value was established for each commodity to allow the calculation of gross in-place values (GIPV) for each tract. In the Level 1 MRA, the dollar value used for each commodity was the average market value of that commodity for the ten-year period from 1981 to 1990. The dollar values used for the Level 2 MRA described in this report are based on either December, 2002 commodity prices or averages for the last ten years.

Industrial Minerals Relative Deposit Value Scores (RDVS)

Metallic and industrial mineral deposit evaluations require different valuing methods. A methodology was developed for the Level 1 MRA project to provide a meaningful comparison between resource assessment tracts based on their industrial mineral potential. This methodology is described in Kilby et al. (1999).

Generally, metals are sold on the world market, they are relatively highly priced, and transportation costs are relatively minor compared to mining and refining costs. Providing that a company can produce the metal at or below market price it can generally sell the product relatively easily. Therefore, metal mines can be developed at considerable distances from population centres or processing plants. With industrial minerals the situation is more complex. Many industrial mineral commodities have low unit values. Thus transportation costs are a major consideration and deposits have to be close to market, or have access to inexpensive transportation, to become producers. This situation exists because the geological resources far exceed the anticipated demand for the commodity in the foreseeable future. For example, in some parts of British Columbia there is excellent potential to locate large limestone deposits in areas where it is impossible to transport the rock or possible products (e.g. cement, lime) economically to the market. In other words, there are significant potential geological resources, but the demand for the commodity limits the value of the resource for the foreseeable future (a relatively uncommon situation for metallic deposits). If the value of in-place resources for deposits like this were used in mineral potential assessments, it would overshadow the value of smaller deposits with readily available markets or high unit values. Since there is a limited market for most of the industrial minerals, estimates of the relative value of industrial mineral resources must often be "capped" to provide a meaningful value for planning processes.

Given the difficulties associated with determining a realistic "gross in place value" (GIPV) for industrial mineral assessments, the GSB developed a new approach. In this process two different assessments are made, one for metallic commodities, and one for industrial mineral commodities. The results are presented separately and no attempt is made to equate or combine the results of the two assessments.

The Level 1 ranking of the land base for metallic deposits is based on the GIPV of commodities in each tract contained in both known and a predicted number of undiscovered deposits. The GIPV of the commodities in each deposit are used to generate a total dollar score per hectare for each tract (Kilby, 1995, 1996). These total dollar scores per hectare are then used to rank all of the tracts under consideration. The GIPV of many industrial mineral deposits is not an acceptable way to compare their relative values because of market constraints. The industrial mineral assessment used a deposit score system where each deposit type was given a "relative deposit value score" (RDVS) from 1 to 100. The RDVS provides a relative ranking for the industrial mineral deposit types and may vary from one geographic area of the province to another. So while the relative deposit rank of metallic deposits is based solely on the value of contained metals or the "gross in place value" (GIPV) industrial mineral deposit relative rankings consider the following characteristics:

- commodity unit-value,
- size and location of potential market,
- deposit grade and size,
- transportation costs,
- existing infrastructure, and
- extraction costs.

In the industrial mineral resource assessment process, the RDVS is used in the same manner as the total GIPV of all the commodities in a metallic mineral deposit to describe the relative value of each undiscovered deposit type.

Resource Estimation

Mineral resource assessments have a long history and an associated large number of assessment methodologies. At the beginning of the Level 1 MRA project a workshop was organized to obtain input from government, university and industry sources on the type of methodology that would be best suited to our required products, our existing databases, our resources and our time constraints. The workshop was held in Victoria, BC on April 22 and 23, 1992. The content and results of the workshop are described in detail in Kilby, 1992.

The estimation procedure that was developed for the Level 1 MRA project incorporated several significant modifications to the USGS three part methodology. In the USGS methodology a single set of estimation values is sent to the simulator. If a group of estimators were involved, this single estimation would have been obtained by consensus. A great deal of work in the field of psychometrics has shown that a true consensus may be unachievable, and certainly would not be achievable within the time constraints most resource assessment projects are faced with. The interaction of people's personalities and agendas would override the information being solicited in a group setting (Acquired Intelligence Inc., 1993). In order to reduce stress and undo influence, each estimator was allowed to make estimates in confidence. The weighting scores provided by the estimators was then used to produce a weighted average of the estimates and obtain a single group estimate for input to the simulator.

The Mark3B simulator requires estimation input at discrete confidence intervals. However, making estimates at specific confidence intervals is believed to restrict the accurate expression of the estimators' true feelings. This is believed to be due to the fact that a great deal of concentration is diverted to thinking about the confidence intervals rather than the estimate being made. An alternative way to record the estimates, and the one used in both the Level 1 and Level 2 MRA projects, is based on fuzzy logic theory. In this method the estimator records the value as a position between two end points. The two end points being, "no chance of a deposit" (0% confidence) and "certainty of a deposit" (100% confidence) (Acquired Intelligence Inc., 1993). The simple linear scale is believed to capture a more realistic sample of the estimator's feelings than the discrete probability level entry style of the USGS three-part methodology. Once the estimates are recorded in this manner discrete probability level values are derived numerically.

Estimation Workshops

The Level 1 MRA involved convening estimation workshops for different regions in the province in order to solicit the required expert estimations for the assessment. Industry and government personnel familiar with a given region and mineral deposit types being assessed were invited to the workshops. These experts were divided into groups of 3 to 4 individuals and each group was assigned a series of deposit types to assess. A large amount of background information, such as the geological compilation, MINFILE occurrence maps and geochemical maps were prepared prior to the workshop to assist the estimators. Today most of this information is provided on-line through the MapPlace web site (www.MapPlace.ca).

Estimators

Estimators were invited to the workshops based on their expertise in the area being assessed and their familiarity with specific deposit types. Naturally, for any given area, one or more individuals might have a better level of knowledge to bring to the table. In order to capture this variability and allow for some weighting of the estimates, each estimator was asked to give a numerical score to their fellow estimators that reflected how they perceived each persons knowledge level. Estimator were not asked to rate their own knowledge level and were automatically given a score of 50.

Workshop Data

Geological information forms the basis of all discussions during both the Level 1 and Level 2 MRA workshops. At the workshops, this basic information was provided as both paper maps at 1:250 000 scale and as online access to the MapPlace web site. Other spatial data sets such as geochemistry, mineral occurrences and tract outlines were usually superimposed on the geology in the form of overlays or plotted directly on the printed maps. In general, as much as possible of the spatial information was made available in the same projection and at the same scale to facilitate efficient use of time by the estimators.

For some data sets it proved to be more important to have the supporting information available in its original format rather than in a totally integrated format because that was how the estimators were familiar with it. Geophysical information, for example, was always made available but was usually in its published format. Though the format was not digital, it was extensively used for some deposit types and proved to be easily integrated by the estimators.

In addition to the information presented in map format, a large amount of material was made available in text format. A compendium of the following information was provided to each estimation table:

- descriptive deposit models
- graphs of the digital deposit models
- a list of all deposit types with their median tonnages and grades
- a small map displaying all tracts in the study area
- a list of all tracts and their areas
- a list of all resource bearing deposits by tract
- a list of all MINFILE occurrences by tract with deposit type information
- a tracking sheet for the table facilitator to log estimates made.

The PC based MINFILE/pc database system was also made available at all workshops.

In addition to information that the project made available at the workshops, estimators often brought company information, usually in the form of private reports or works in progress that proved extremely useful. This private information was freely shared at the estimation tables and was essential to the success of the process. More important still was the personal experience and knowledge of the estimators; it was key to the success of the assessments.

Estimation Process

Each Level 1 estimation workshop began with a presentation that described the estimation process, its rules, the information available, the estimator's responsibilities and how the estimation results would be processed. A second presentation by a geologist involved in the area's geological compilation and tract selection described the geology and metallogeny.

The invited estimators were divided into groups of 3 to 4. Each group was assigned a series of mineral deposit types and their task was to provide estimates for each tract in the entire study area. For example, they might be asked to estimate the number of copper and iron skarns and multi-element veins deposits for the whole of Vancouver Island. Each group or table consisted of these estimators and one facilitator. The facilitator's purpose was to keep the process on track, manage the coding sheets and make sure the rules of estimation were followed. The facilitator did not make any estimates but was free to participate in any discussions or assist in any way possible. Each group was assigned a table to work at and all tables were relatively close to each other to promote consultation with other tables should the need arise.

Four basic guidelines were followed by the estimators:

1) The estimators made their own estimate in confidence. No table consensus was sought.
2) Each person made a confidential evaluation of the other estimators with respect to each tract/deposit model combination.
3) If all estimators agreed that a particular deposit type would not be found in a tract, then no estimate was made, but if at least one estimator felt there was a chance for the deposit type to occur in the tract then everyone made an estimate.
4) The deposit size, for this process, was the median tonnage of the digital deposit model for the deposit type.

A typical sequence of actions for the estimate of a single tract/deposit type combination would be:

1) A general table discussion of the tract geology and the characteristics of the deposit type would often result in the group identifying characteristics of the tract that were favourable for the deposit type. All available information sources would be used during this step, such as MINFILE, geochemistry, geology, geophysics and personal knowledge.
2) The group would identify any known occurrences of the deposit type being estimated from MINFILE. Care was taken to properly include these known occurrences. So long as an occurrence did not have defined resources, it was included in the estimates of undiscovered deposits. If it had significant known resources but was not expected to be enlarged through additional exploration by at least the amount of the digital deposit model median tonnage, it was excluded because the resources would be counted as inventory. If it was felt that there was an opportunity for the deposit to be increased in size by at least the amount of the median tonnage, an estimate for this additional amount could be considered in estimators' evaluation. In this case, the already known resources would be considered as inventory and the potential new resources possible through additional exploration would be considered as potential resources.
3) When each estimator recorded estimates for a single deposit type they would do the following:
    - ❖ Ask themselves "How confident am I that at least one more deposit of the median tonnage size can be found in this tract?" They would then place a tick mark on the estimation scale and the number one above it to record the number of deposits associated with the estimation tick mark (Figure 3).
    - ❖ Then they would proceed by asking themselves how confident they were that at least two deposits of the median tonnage could be found. In this instance the probability estimate tick mark is labeled 2. Estimators were not restricted to

increments of one deposit but could choose any number that was appropriate. They were, however, limited to a total of six tick marks on the scale.

- ❖ Then if they wished, they could add a single tick mark to the scale, which recorded the confidence level, at which they were confident no deposits could be found. This option was often confusing and required care in use. If this option was not provided, then the simulator assumed a default value for zero deposits because the program always assumes that there are some chance of the deposit type existing. Although this feature is used to help constrain the simulator, it was seldom used by the estimators.
- ❖ Following completion of their estimates, they were required to evaluate each of the other estimators for that tract/deposit type combination. To do this they recorded the estimators' initials and record a ranking score. They were required to distribute 50 ranking points between the other estimators at the table. In this way they could adjust the weight placed on the others' estimates in accordance to their feeling of each person's knowledge of the tract and deposit type.
- ❖ Finally the estimators would place one tick on the estimation confidence scale recording their overall feeling of the quality of that estimate. This was not a measure of their confidence in their own estimation but was a measure of their confidence in the quality of the estimation made by the group as a whole that included the general group knowledge of the tract and deposit type, the quality of the information available and the quality of the estimators. This value is not used in calculating the potential of the tracts but has value for gauging the quality of the estimate should the issue arise in the future.

4) Once all the estimates for the tract/deposit type combination were completed, the facilitator would check to make sure all required information had been recorded and then staple all the work sheets together.
5) The table would then move on to the next tract/deposit type combination.

Pre-Simulation Estimate Preparation

Upon completion of the estimation of the potential for undiscovered mineral deposits in a tract, the information captured on the coding sheets was converted into digital files. These files were then processed to provide input into either the Mark3B simulator or the industrial mineral evaluation process.

The estimation coding sheets were processed once a workshop was completed. The initial step was to digitize the linear Estimate Scale on each sheet. This digitization involves measurement of the distance along the estimation bar, from 0 to 100 for each tick mark made by the estimator.

Once all the estimation-coding forms were digitized the information was recorded into computer files. Upon completion of the data entry phase, the multiple estimates for each group/tract/deposit combination must be reduced to a single weighted estimate based on the weights assigned by each estimator at the table. The QuickBasic program RAW2MARK.exe written by Ward Kilby produces a single weighted estimate for each tract/deposit type. Two output files are created by the program, one containing a script of input values for the Mark3B simulator and the other containing the weighted estimates of the number of deposits that the group thought could be found in the tract at the 90, 50, 10, 5 and 1 percent confidence levels. The program uses linear interpolation between the values noted on the coding sheet to calculate the number of deposits expected at the five discrete confidence points needed for input to the Mark3B simulator. Simple weighted averaging is used to combine all the estimates for a single tract/deposit type combination.

As described earlier, each estimator was required to rate each of the other estimators at the table by distributing 50 ranking points between the other estimators based on the estimator's feeling of their relative knowledge of the deposit type and tract being estimated. Each estimator was also assigned 50 ranking points to assure that each estimator's estimations provided at least some input to the group estimate as the estimators could not apply any ranking points to their own estimations. Thus the total number of points for any estimate would be 100 times the number of estimators. The weighting of each estimator's values in the combined result would then be their total number of points divided by the total number of points for the whole table.

Industrial Mineral Resource Calculation

As described earlier, the industrial mineral (IM) resource assessment calculations differ from those performed for metallic minerals. The processing of the estimate information for the two types of commodities diverges after the weighting stage. Once the weighted mean estimates for each IM deposit type in each tract have been calculated, the deposits are valued by multiplying the number of deposits by the RDVS.

At this point, the estimate portion of the industrial mineral assessment is ready to be integrated with tract area and inventory information to allow final tract ranking calculations to be performed. This integration and calculation step is performed in MS Access. Two MS Access queries are used to perform some simple calculations on this data, add some additional fields and perform the ranking of the tracts.

The calculations performed in MS Access are identical for industrial minerals and metallic minerals. The only difference is that the values in the estimation fields for metallic commodities are in pseudo-dollars and the corresponding values for industrial minerals are RDVS.

Mark3B Mineral Resource Assessment Monte Carlo Simulator

The original Mark3 simulator was developed by the USGS and has been used in many mineral resource assessment projects (Brew, 1992, Brew et al., 1991, Cox and Singer, 1986, Cox, 1993, Root et al., 1992 and Spanski, 1992). An excellent example of one of these projects, and a description of the operation of the simulator, can be found in Root et al., 1992. The simulator itself was released in 1998 (Root et al., 1998). Originally the simulator was available in the Fortran computer language and required significant computer resources to operate. During the Level 1 MRA project the Mark3 simulator was rewritten in QuickBasic by the USGS so that it could be operated on the more common PC platforms. This new simulator was called Mark3B to designate its QuickBASIC source code. This QuickBASIC version was provided to the GSB along with considerable advice and recommendations (Root, Pers. Commun. 1993). The Mark3B was modified slightly to provide a custom output file that simplified the data processing involved in producing tract rankings. The functions of the simulator have been described elsewhere (Brew, 1991 and Root et al., 1992) but the eleven basic steps that the simulator goes through during a calculation are summarized here (from Root, unpublished).

1) Choose, at random, the number of deposits for this iteration. If it is zero, go to step 10 otherwise go to step 2.
2) Choose, at random, a suite of metals. Go to step 3.
3) Evaluate, at random, m+1 independent standard normal random variables (m= the number of metals in the model). Go to step 4.
4) Calculate the linear combinations of the values of the standard normal random variables from the matrix of coefficients in the “bem” file to obtain the values of m+1 dependent standard normal random variables. Go to step 5.
5) Find dependent uniform values from the dependent standard normal random variables (by the inverse of the cumulative standard normal distribution function evaluated at the values determined in step 4). Go to step 6.
6) Find tonnage and grade values from the dependent uniform values and the inverse of their cumulative distributions. Go to step 7.
7) Add the amount of each metal to its total for the deposits in this iteration. Go to step 8.
8) Check to see whether there is another deposit to do in this iteration. If there is, go to step 2, otherwise go to step 9.
9) Check to see whether 4,999 iterations have been completed. If not, go to step 1, otherwise go to step 10.
10) For each metal, sort the 4,999 totals from each iteration (least being rank1 and greatest being 4,999).
11) Graph 1 minus the rank divided by 4,999 on the y-axis versus the quantity of metal on the x-axis to obtain the assessed distribution of the metal in the area.

In addition to the above steps, a modification to the program extracted the total amount of each commodity calculated for each tract at five probability ranks (0.9, 0.5, 0.1, 0.05, 0.01) and output this information into a file called SIMTOT.all.

Operation of the simulator can be performed either in interactive or batch mode. With the output from the

RAW2MARK.exe program the batch mode of operation is very straightforward.

The results in the simulator output, SIMTOT.all, are the tract number, the deposit type number, the commodity, a mean tonnage value, and the volume of the commodity in tonnes expected to be discovered at the five confidence levels (.9, .5, .1, .05, .01). The next step in the processing of the metallic mineral estimates is to convert the commodity amounts to dollar values to allow integration of all the commodities into one value for the deposit and subsequently the tract. This can be done easily in either MS Access or MS Excel or by using the SIM-VALU program created by Ward Kilby.

Once total tract dollar values have been calculated, this number is normalized for tract area to give a GIPV per hectare value. In the Level 1 MRA this value is integrated with inventory information to allow final tract ranking calculations to be performed. This integration and calculation step is performed in MSAccess.

Post-Simulation Calculations

Final ranking of tracts for both the metallic and industrial minerals assessment are performed in exactly the same way once the valued estimation information has been merged with the resource inventory and tract area information. MS Access is used to perform the manipulations required to produce the final rankings. The calculations are all based on a per hectare basis. In the calculations, each tract is ranked using each of the six confidence interval values individually, and then the six rankings are weighted by their probability and combined to produce the final rank value.. This is done to isolate the estimates at the various confidence levels so they do not bias the final ranking score. This approach prevents an extremely high ranking at a low confidence level from overshadowing a lower ranking at a high confidence level.

For each of the variables (confidence interval levels), the tract is assigned a rank based on that variable normalized for the size of the tract (area). The rank numbers run from one, for the lowest ranking, to the total number of tracts for the highest ranked tract for that variable. The rank numbers for each variable are then weighted by their confidence value and summed to give a total score for each tract. For the final ranking, the scores for each of the tract are sorted from lowest to highest and assigned ordinal numbers from 1 to the total number of tracts (794) to give the final ranking.

The weightings assigned to the variables are, 1.0 for the inventory values, .9 for the 90% confidence values, .5 for the 50% confidence values, .1 for the 10% confidence values and .01 for the 1% confidence values.

Tract Ranking Maps

Two provincial scale maps were generated to display the relative ranking of the mineral potential across the province for the Level 1 MRA. One map illustrated the mineral potential ranking based on the metallic mineral commodities and the second map illustrated the mineral potential based on the industrial mineral commodities. These maps are useful to illustrate very broad trends in the potential but are not valid for detailed analysis of tract rankings. The maps do not include any measure of important variables that have affected resource development in the province such as regional exploration histories and infrastructure development. The mineral assessment evaluation was carried out on a regional basis. Comparison of tract rankings from widely separated regions may result in flawed analysis due to their very different histories. Two tracts may have exactly the same mineral potential but due to the remote location of one relative to the other it will not have received the exploration attention over time and will likely have a lower mineral potential ranking than the tract that received the most exploration. Detailed comparison of tract rankings within a region or closely separated tracts in two adjacent regions is valid, as they will in most cases have shared a common exploration and developmental history.

Limitations of Mineral Resource Assessments

Mineral Resource Assessment maps and products are a very valuable component in any land use planning process. In jurisdictions containing substantial mineral resources such as British Columbia they are essential. Although considered essential to the process they are only a component of the information needed to make an informed decision on land use. There are a number of limitations to any Mineral Resource Assessment product.

Time Related Issues

The principle limitation is the timeliness of the assessment. All assessments are made based on historic information and current knowledge. They are therefore, a snapshot in time. They cannot be expected to accurately portray the mineral potential of a portion of land far into the future. Our knowledge of mineral deposits will advance with time changing our ability to discover and develop deposits in unimagined environments, at greater depths and with lower grades. New technologies will allow certain deposit types to be discovered with greater ease and will allow the profitable exploitation of deposits that are currently uneconomic. In addition deposit types that were not believed to exist in the study area during the analysis may subsequently be found within the area. Societal demands for certain commodities will change causing the relative values of deposits to change and thus the relative ranking of mineral assessment tracts.

Scale Related Issues

The Level 1 MRA was conducted at a scale of 1:250 000. This scale was dictated by the client of the information and was used to present all resource evaluation information from all sectors to the various planning processes. The scale of analysis dictates the required resolution of the analysis units (tracts). Tract size limits the size of planning areas in which the tract can provide any information of value in differentiating the planning area. For example, if a planning area contains a single mineral assessment tract the mineral assessment information adds nothing to the planners' abilities to subdivide the planning area on the basis of mineral potential. In British Columbia as the planning process progressed, smaller and smaller study areas were proposed and land use planning initiated. In some LRMP areas only a few 1:250 000 scale mineral assessment tracts covered the whole LRMP. In these small areas an analysis of greater detail than the initial 1:250 000 study was required to be able to make any reasonable contribution with respect to mineral potential.

In some cases, the information in the provincial scale MRA can be used to generate a more detailed product without conducting a new estimation of undiscovered resources. Usually, the mineral resource assessment tracts contain a variety of geological units. The units, though grouped at a scale of 1:250 000, may in fact be permissive for different types of mineral deposits. If deposit types contributing significantly to the total value of a tract prove to be controlled by geological or topographical features that can be delineated within the tract then the associated values of known and estimated resources can be placed in these sub-tracts. By this means it may be possible to extract greater spatial resolution from the original study without performing a new assessment but simply redistributing the previously calculated values. These more detailed assessments are referred to as Level 2 MRAs.

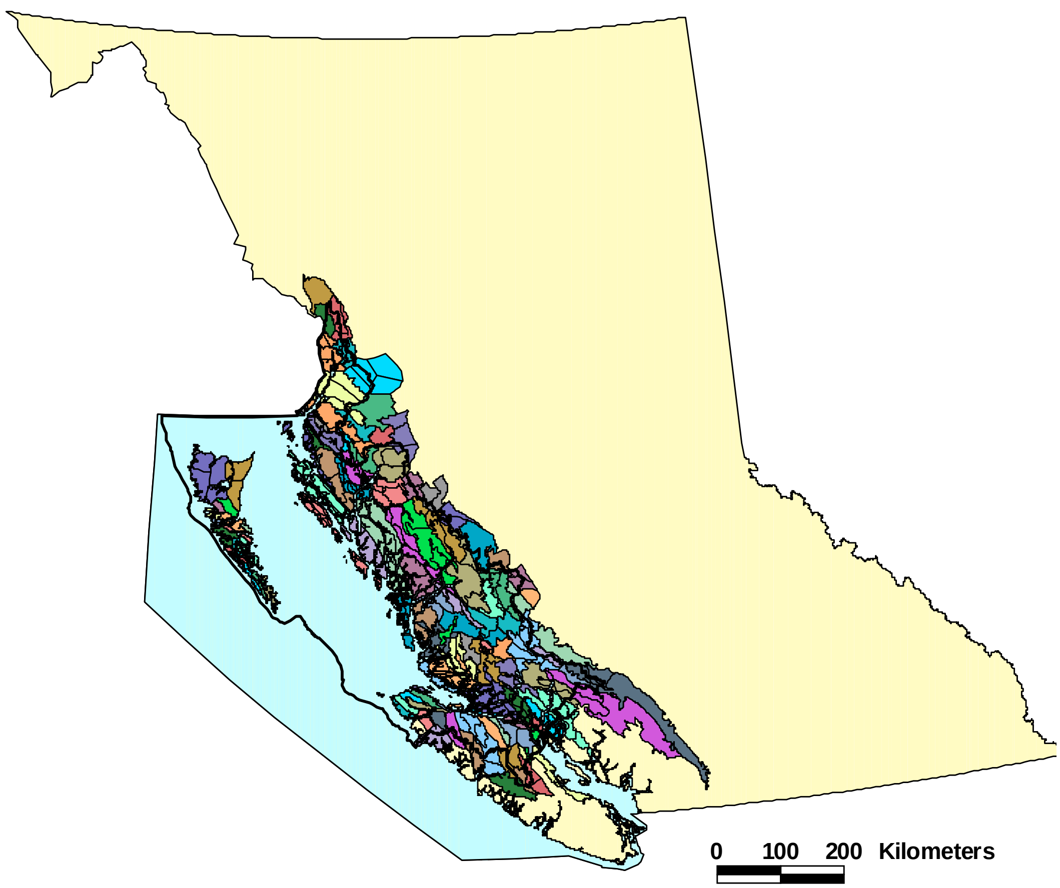

Figure 2. MRA Tracts, CIT Project Area

CIT Mineral Resource Assessment (Level 2)

In order to provide a more detailed MRA for the CIT project area, a Level 2 assessment was conducted in October, 2002. This assessment incorporates elements from the Level 1 assessment (Bellefontaine and Alldrick, 1994, 1995; MacIntyre et al., 1994, 1995; Massey, 1994, 1995) for undivided tracts and a preliminary Level 2 MRA applied to selected tracts within the North Coast LRMP that was done in February 2002.

The following tasks were completed in chronological order to produce the final Level 2 MRA for the CIT project area.

Selection of MRA tracts for subdivision

Existing Level 1 MRA tracts that intersected or were within the CIT project area were examined and candidate tracts for subdivision were selected. All tracts with significant area within the CIT boundary and in excess of 100,000 hectares were targeted for subdivision (Table 1). A list of these tracts was prepared and submitted to MSRM and CIT for consideration. A final list of tracts was compiled together with pertinent information from the Level 1 MRA. A preliminary map in ESRI shape file format showing the tracts targeted for subdivision (Figure 2) was prepared and posted to a MapGuide website prepared especially for this project (http:/webmap.em.gov.bc.ca/mapplace/minpot/cit.cfm)

Invitation to Quote for Metallic and Industrial Mineral Experts

Upon approval to proceed with the project an Invitation to Quote (ITQ) was prepared and posted to the BC-Bids website inviting metallic and industrial mineral experts with knowledge of the CIT project area to participate in an "experts workshop" to be held in Victoria during the period October 7 to October 18. Selection of participants was based on a review of pertinent credentials and their daily contract rate. A copy of the ITQ is included in Appendix 1. The ITQ included a map showing the tracts targeted for subdivision and a listing of the deposit models in each tract for which redistribution estimates were required.

Expert Workshops

Two separate workshops were convened. The first was held October 7 to October 11 and dealt with the redistribution of metallic mineral resources in the project area. A total of six experts participated in this workshop. This group was divided into two tables of 3 experts each plus a GSB facilitator. Each table made redistribution estimates for all of the tracts in the project area. The second workshop was held October 14 to October 16 and involved a single table comprised of 4 industrial minerals experts and a GSB facilitator.

The first task assigned to the metallic mineral tables was to examine the geology of the existing Level 1 tracts targeted for subdivision and decide how they should be subdivided. Depending on the complexity of the geology within the tract, anywhere from 1 to 5 sub-tracts were defined (Table 1). Sub-tract boundaries were drawn directly onto coloured geology maps that were plotted specifically for the project. Sub-tracts were given a numeric label i.e. 1, 2 etc. The industrial minerals table that was convened the following week used the same sub-tract boundaries established by the metallic mineral experts.

Table 1. MRA Tracts, CIT Project Area

LRMP	Tract Id.	Hectares	Sub-tracts
carib-chil	CP5CN_CARI	83600	
carib-chil	NP1C__CARI	101442	2
ccoast	CNC-2_SKEE	196127	3
ccoast	CNC-4_SKEE	205474	2
ccoast	CNC-5_SKEE	102399	2
ccoast	CNC-7_SKEE	155428	2
ccoast	CP1___SKEE	240293	4
ccoast	CP2___SKEE	413922	3
ccoast	CPC-11SKEE	217833	4
ccoast	CPC-12SKEE	204289	3
ccoast	CPC-15SKEE	145920	2
ccoast	CPC-16SKEE	79154	
ccoast	CPC-17SKEE	189211	2
ccoast	CPC-20SKEE	97923	2
ccoast	CPC-21SKEE	167322	2
ccoast	CPC-23SKEE	232250	3
ccoast	CPC-24SKEE	88652	
ccoast	CPC-25SKEE	159159	2
ccoast	CPC-26SKEE	35459	
ccoast	CPC-27SKEE	109755	3
ccoast	CPC-28SKEE	191866	2
ccoast	CPC-30SKEE	156103	3
ccoast	CPC-31SKEE	134493	2
ccoast	CPC-33SKEE	81193	
ccoast	CPC-34SKEE	128015	3
ccoast	CPC-6_SKEE	219314	3
ccoast	G-1___SKEE	28700	
ccoast	GA-5__SKEE	122108	2
ccoast	GA-6__SKEE	356176	3
ccoast	JH3___SKEE	61283	
ccoast	KJ13__VANI	29718	
ccoast	KJ20__VANI	14273	
ccoast	KK1___SKEE	62266	
ccoast/carib-chil	CP7N__CARI	119167	2
ccoast/lakes	ST-1__SKEE	237931	
ccoast/lmainland	CPC-10SKEE	299583	4
ccoast/lmainland	CPC-14SKEE	99613	2
ccoast/lmainland	CPC-19SKEE	43140	
kalum	CP12__SKEE	234439	3
kalum	CP18__SKEE	84359	
kalum	CP3___SKEE	102999	2
kalum	JH19__SKEE	216835	3
kalum	JH7___SKEE	88222	
kalum	KK2___SKEE	59270	
lmainland	CP3NKJCARI	51519	
lmainland	CP6CN_CARI	56966	
lmainland	WC1___THOK	465098	
lmainland/carib-chil	CP8N__CARI	61282	
lmainland/carib-chil	CP9NOKCARI	157120	3
lmainland/lillooet	EC6___THOK	451558	
ncoast	CP11__SKEE	254053	6
ncoast	CP13__SKEE	103010	2
ncoast	CP14__SKEE	33627	
ncoast	CP15__SKEE	128173	2
ncoast	CP16__SKEE	233464	3
ncoast	CP17__SKEE	93980	
ncoast	CP19__SKEE	53115	
ncoast	CP20__SKEE	98408	5
ncoast	CP21__SKEE	34026	
ncoast	CP22__SKEE	341543	4
ncoast	CP6___SKEE	208958	3
ncoast	CP7___SKEE	127843	6
ncoast	CP8___SKEE	128219	2
ncoast	CP9___SKEE	195234	3
ncoast	JB5___SKEE	399709	4
ncoast	JH25__SKEE	141509	4
ncoast	JH26__SKEE	169440	3
ncoast	JH28__SKEE	147573	2
ncoast	JH29__SKEE	82441	
ncoast/ccoast	CNC-6_SKEE	222515	4
ncoast/ccoast	CP10__SKEE	235589	5
ncoast/ccoast	CPC-29SKEE	410476	5
ncoast/ccoast	CPC-35SKEE	202358	3
qci	1_____QCIS	180743	2
qci	10____QCIS	26410	
qci	11____QCIS	42785	
qci	12____QCIS	37257	
qci	13____QCIS	31098	
qci	14____QCIS	40338	
qci	15____QCIS	9273	
qci	16____QCIS	4729	
qci	17____QCIS	18710	
qci	18____QCIS	28315	
qci	19____QCIS	63178	
qci	2_____QCIS	328192	4
qci	3_____QCIS	14031	
qci	4_____QCIS	23518	
qci	5_____QCIS	48815	
qci	6_____QCIS	15140	
qci	7_____QCIS	23860	

qci	8_____QCIS	16019	
qci	9_____QCIS	54145	
van_isl	KJ10__VANI	17668	
van_isl	KJ11__VANI	26984	
van_isl	KJ12__VANI	134636	2
van_isl	KJ14__VANI	38895	
van_isl	KJ15__VANI	85176	
van_isl	KJ18__VANI	114645	2
van_isl	KJ19__VANI	93924	2
van_isl	KJ22__VANI	97963	
van_isl	KJ23__VANI	99226	2
van_isl	KJ24__VANI	52545	
van_isl	KJ25__VANI	41810	
van_isl	KJ27__VANI	43224	
van_isl	KJ28__VANI	45200	
van_isl	KJ29__VANI	46469	
van_isl	KJ30__VANI	35827	
van_isl	KJ31__VANI	11222	
van_isl	KJ32__VANI	2138	
van_isl	KJ33__VANI	38670	
van_isl	KJ6___VANI	113735	2
van_isl	KJ8___VANI	137044	
van_isl	KJ9___VANI	121106	2
van_isl	N3____VANI	121326	
van_isl	N5____VANI	12858	
van_isl	S4____VANI	46308	
van_isl	S5____VANI	196064	3
van_isl	W5____VANI	15514	

Once the sub-tract boundaries were established, coding sheets were handed out for each tract being subdivided. As shown in Figure 2, these sheets contained information from the Level 1 MRA such as dollar values for inventory, exploration expenditures, number of Minfile occurrence, tract hectares, etc., plus columns for each of the deposit models considered in the Level 1 MRA. Blank columns were also provided for any new deposit model estimates. These

Table 2a. List of industrial mineral deposit models, CIT project area

Deposit Code	Profile Code	USGS code	Model Name
13i		13i	U-Th Pegmatite
37k		37k	Metamorphic Garnet
B6	B05	38h	Residual Kaolin
B7	B05		Fireclay
Barite	E17	31b	Barite (Kuroko association)
Basalt			Columnar Basalt
D6	D01	25oa	Zeolites In Tuffs Of Open Hydrolic Systems
D7	D02	25ob	Zeolites
E10	E07	31k	Sedimentary Kaolin
E10a	E07		Sedimentary Kaolin (blue clay)
E6b	E08	18?I	Carbonate-hosted Talc
E9	E06	28e?	Bentonite
F4a	F02	35ae	Bedded Gypsum/Anhydrite
F8b	F06?	31s?	Diatomite
Feldspar			Feldspar
Granite	R03		Granite
Gypsum	G03		Gypsum
I11	H09	25ib	Hydrothermal Alteration Clays-Al-Si
K7	I07		Silica Vein
N10	K09	18g	Wollastonite Skarn
N9	K08		Garnet Skarn

P6	M06	8d	Ultramafic-hosted asbestos
Peridot			Peridote
Q1	N01	10	Carbonatite-hosted deposits
R2	P02		Kyanite Family
R4	M07	8f	Talc
R5	P03	18k	Microcrystalline Graphite
R6	P04	37f	Crystalline Flake Graphite
S1a	Q11		Opal
S2b	Q02		Rhodonite
T1	R01		Cement Shale
T10	R11	IM25ka	Pumice
T11	R12		Perlite
T13	R14		Alaskite
T14	R15		Crushed Rock
T2	R02		Expanding Shale
T3	R03		Dimension Stone Granite
T4	R04		Dimension Stone Marble
T5	R05		Dimension Stone Andesite
T6	R06	30	Dimension Stone Sandstone
T8	R08		Flagstone
T9	R09/R10		Limestone/Dolostone
T9A	R09/R10		Limestone/Dolostone (WHITE)

Table 2b. Metallic mineral deposit models in the CIT Project area

Deposit Code	Profile Code	USGS code	Mark 3B model no.	Model Name
C1	C01	39a to e		Placer Au
C2	C01	39a to e		Paleoplacer (Garnet)
C3	C03	39f?		Marine Placer
D1	D03	23	2	Volc. Redbed Cu
D2	E04	30b	63	Sediment-hosted Cu
EC	G07		90	Eskay Creek
F1	F01	34b		Sedimentary Mn
H2a	S01	31a	13	Broken Hill type Pb-Zn-Ag±Cu
H4	G04	24b	30	Besshi Massive Sulphide
H4/H6	G04/G05	24a/24b	39	Besshi/Cyprus Massive Sulphide (Merged)
H5	G06	28a	36	Noranda/Kuroko Massive Sulphide
I4	H03	25a	45	Hot-Spring Au-Ag
I5	H04	25d	28	Epithermal Au-Ag: High Sulphidation
I6	H05	25c	25	Epithermal Au-Ag: Low Sulphidation
J13	I08	27c		Silica-Hg Carbonate
J2	I09	27d,27e	26	Stibnite Veins/Disseminations (Combined)
J3	I02		27	Intrusion-related Au Pyrrhotite Veins
J4	I01	36a	43	Au-Quartz Vein

J5	I04	36b	1	Iron Formation Au (Homestake Au)
K1	J03	19b	31	Mn Veins and Replacements
K5	I05	22c,25b	29	Polymetallic Ag-Pb-Zn Vein
N1	K01	18a,18b	9	Cu Skarn
N3	K02	18c	22	Zn-Pb Skarn
N4	K03	18d	7	Fe Skarn
N5	K04	18f	23	Au Skarn
N6	K05	14a	24	W Skarn
N8	K07		95	Mo Skarn
O1	L01	22a,25e	94	Subvolcanic Cu-Ag-Au (As-Sb)
O2	L04	17,20,21a1	4	Porphyry Cu-Mo-Au
O4	L03		92	Alkalic Porphyry Cu-Au
O5	L02	20d	42	Porphyry Related Au
O7	L08	16	5	Porphyry Mo (Climax-type)
O8	L05	21b	6	Porphyry Mo (Low F- type)
P2	M02	7a	19	Tholeiitic Intrusion-hosted Ni-Cu
P3	M03	8a,8b	91	Podiform Chromite
P5	M05	9	14	Alaskan PGE

columns were labeled with the deposit code used in the original MRA. A lookup sheet was provided so that these codes could be cross-referenced to existing deposit profiles (Tables 2a, 2b).

For each sub-tract, a row was added to the table grid and a brief description of the primary geologic features of the sub-tract entered in the cell next to the sub-tract number.

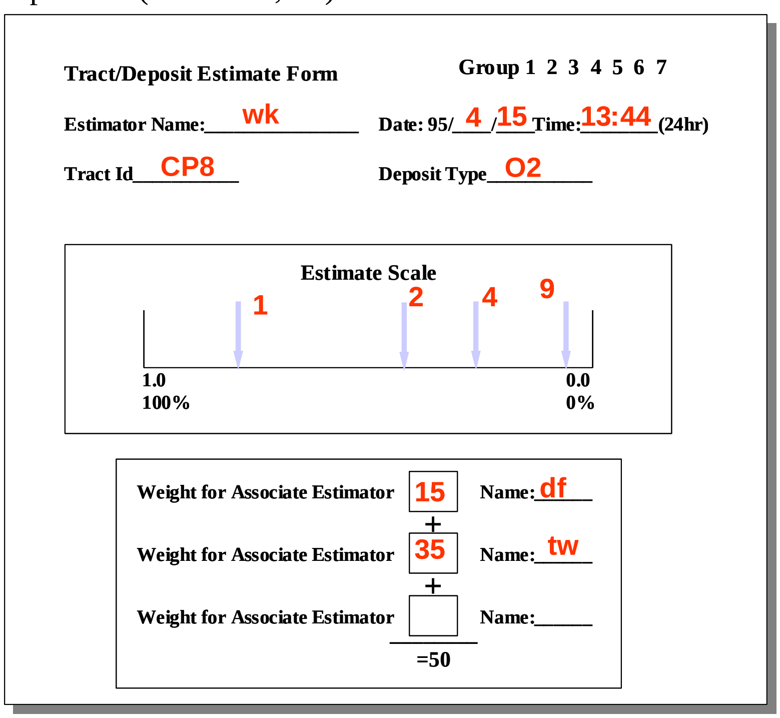

Figure 3. Tract/deposit estimate form used in Level 1 and Level 2 MRA projects. A form is completed by each estimator for each tract-deposit model combination. The form has a linear bar scale where estimators place tics and record the number of deposits expected to be discovered at various confidence levels.

For each deposit model, the experts were given time to discuss the likelihood of that type of deposit occurring in each of the sub-tracts. To assist this discussion, the facilitator used a notebook computer connected to the Internet and a digital projector to display information on the geology, mineral occurrences, geochemistry and geophysics in the vicinity of the tract under consideration. Most of this information was derived on-line from the MEM MapPlace website (www.mapplace.ca). Also included in the discussion was an evaluation of the models considered in the Level 1 MRA and whether new models should be estimated for. If the table decided that new models should be considered, estimation forms for that model (Figure 3) were distributed and the experts were asked to fill these out using the same methodology used in the Level 1 MRA. Once this task was completed the experts were then asked to indicate the percentage of each deposit model estimate that should be assigned to each sub-tract. These redistribution percentages were based on the geologic characteristics of the sub-tracts and the relatively likelihood that a particular deposit model would occur in that sub-tract. In some cases, because the deposit model was not strongly controlled by a specific geologic characteristic there would be roughly equal likelihood that a deposit might be found in each of the sub-tracts. For other deposit models, such as those associated with specific rock types such as intrusions, the occurrence or absence of these features in a sub-tract would significantly influence the percentage of the original estimate to be assigned to that sub-tract (Figure 4). Naturally, column totals for each deposit model must total 100%. The experts were also asked to indicate on the redistribution form a personal confidence level (PCL) as a score out of 100, which would reflect how they felt about their personal knowledge of the tract and mineral deposit models being discussed. In addition, they were also asked to rank the other experts at the table by assigning points, the total of which must add up to 50.

Estimator: NC   Date: 2002/10/7   Time: ______

LRMP	Tract ID	Hectares	Minfile Occs.	Metallic Inventory $86	Exploration Expenditures $86	Past Production $86	Ind. Min Inventory $86	Metallic Rank (794 highest)	Ind. Min. Rank (794 highest)	Region			
ncoast	CP8__SKEE	127464	2	0	2827	0	0	80	135	SKEE			

Sub-tract	Primary Feature	Deposit Models								
		C1	H4/H6	H5	J4	K5	O2	O8		
		%	%	%	%	%	%	%	%	%
1	Predominantly granite	50	10	10	50	50	90	90		
2	Predominantly meta.	50	90	90	50	50	10	10		
		100%	100%	100%	100%	100%	100%	100%	100%	100%

Associate Estimators

	Initials	Weight (%)
1	AP	30
2	AB	20
3		
4		
		must = 50%

Remarks: PCL-85%

Figure 4. Redistribution estimation worksheet used in the CIT Level 2 MRA project.

Data Processing

Data processing was done by GSB staff and began immediately after the expert workshops were completed. The first task involved processing 155 metallic and 484 industrial mineral deposit estimation forms. For each estimator and each deposit model this involved measuring the location of tics on a probability bar, converting these values to a probability percentage, recording the number of deposits estimated at each probability level and recording the weights given to the other estimators at the table. This raw data was entered into separate excel spreadsheets for metallic and industrial mineral deposits (Appendix 2 and Appendix 3). This data was then reformatted and exported as a comma delimited ASCII file (Appendix 4 and Appendix 5) for input into the RAW2MARK QuickBasic program written by Ward Kilby. This program calculates the weighted average number of deposits for each deposit model at the 99, 90, 50, 10 and 1 percent confidence levels. The results of these calculations are given in tables 3 and 4 respectively.

The second data processing task involved entering the redistribution percentages, personal confidence levels and weights assigned to the other estimators at the table from the redistribution worksheets (Figure 4). Redistribution percentages were recorded in an MS Excel spreadsheet (Appendix 6 and Appendix 7) with one record created for each value recorded on the worksheets (6240 metallic and 2681 industrial mineral records). Personal confidence levels and weights given to associated estimators were entered in separate spreadsheets (Appendix 8 and Appendix 9). All this data was imported into an MS Access Database where a series of queries were used to calculate a weighted average redistribution percentage for each deposit model in each sub-tract. Appendix 10 and Appendix 11 show a comparison of the average raw and weighted percentages calculated for each sub-tract and deposit model. These percentages were then applied to existing Level 1 estimates of the number of undiscovered deposits at the 99, 90, 50 , 10 and 1 confidences levels and new estimates completed as part of this project (Tables 3 and 4) to give a new set of redistributed values for each sub-tract-deposit model combination (Files Appendix 12 and Appendix 13).

Once the estimated number of undiscovered deposits at the 5 confidence levels had been tabulated for each of the tracts and sub-tracts in the project area, this data was reformatted for input into the Mark3B resource simulator (Appendix_14). The input required to run the simulator includes the tract number, deposit model number, number of iterations to perform, number of confidence levels to use and the estimated number of undiscovered deposits at each of the confidence levels. Since the tract names are too long for input into the simulator a key number was created for each tract and subtract (see Appendix 13). The deposit numbers used by the simulator correspond to the names of a series of files containing commodity, grade and tonnage information (Table 2) used in the Monte Carlo simulation process. For this project the number of iterations for each tract-deposit model combination was set at 2000 and estimation data was entered for the 90, 50 and 10 percent confidence levels. The input file used to run the simulator in batch mode is shown in Appendix 14 and Appendix 15 describes the simulator operation and input options. The output from the simulator is written to a comma-delimited, ASCII text file (SIMTOT.ALL). Each record has the tract number, deposit, number, commodity name and predicted tonnes for the mean and 90, 50, 10, 5 and 1 percent confidence levels. One of the problems that were recognized after the first run of the simulator involved the rounding off the number of undiscovered deposits entered as input to the nearest whole number. For example, for two adjacent tracts (or sub-tracts) estimates for the number of undiscovered deposits of a specific deposit model at the 90, 50 and 10 confidence levels might be entered as 0.5, 1.5, 2.5 and 0.51, 1.51 and 2.51 respectively. The simulator program would round these numbers to 0, 1, 2 and 1, 2, 3 respectively and the

Table 3. New estimates for metallic mineral deposits added to the CIT Level 2 MRA.

Tract	Model	Confidence Level				
id	code	99%	90%	50%	10%	1%
CNC-2_SKEE	K5			0.78	1.67	1.67
CNC-5_SKEE	N3			0.84	2.33	2.33
CPC-12SKEE	H5			0.74	2.33	2.33
CPC-15SKEE	I6			0.33	1.50	1.50
CPC-17SKEE	H4/H6				1.33	1.33
CPC-17SKEE	H5			0.57	1.67	1.67
CPC-17SKEE	K5			0.57	1.66	1.67
CPC-21SKEE	H4/H6				1.33	1.33
CPC-21SKEE	H5			0.20	1.33	1.33
CPC-21SKEE	K5			0.94	1.80	1.83
CPC-27SKEE	K5			1.49	2.27	2.33
CPC-30SKEE	N1			0.51	1.65	1.67
CPC-34SKEE	N1			0.76	1.82	1.84
CPC-34SKEE	N5			0.25	1.52	1.52
CP1___SKEE	J5		0.20	1.24	2.37	2.37
CP1___SKEE	K5		0.20	1.82	2.87	2.87
CP1___SKEE	N3			0.81	2.01	2.01
CP2___SKEE	N1			0.23	1.64	1.67
KJ18__VANI	EC			0.23	1.64	1.67
CP15__SKEE	H4/H6			0.73	1.99	2.00
CP15__SKEE	H5			0.49	1.83	1.83
CP9___SKEE	H4/H6			0.24	1.33	1.33
CP9___SKEE	H5			0.24	1.33	1.33
CNC-6_SKEE	H4/H6			0.17	1.33	1.33
CNC-6_SKEE	H5		0.25	1.23	2.36	2.45
CP9NOKCARI	H4/H6				1.47	1.47
CP9NOKCARI	H5				1.47	1.47

Values shown are the weighted mean number of median size deposits that the expert panel estimated for the indicated deposit type and confidence level. These values were calculated by the RAW2MARK.exe program using the input shown in Appendix 4.

Table 4. New estimates for undiscovered industrial mineral deposits added to the CIT Level 2 MRA

Tract id	Model code	Confidence Level				
		99%	90%	50%	10%	1%
CP9NOKCARI	37k			0.36	1.25	1.25
CP9NOKCARI	R6			0.31	0.98	1.25
CP9NOKCARI	R2			0.30	1.25	1.25
CPC-14SKEE	T9a			0.40	2.33	2.33
CPC-14SKEE	N10			0.71	1.25	1.25
CPC-10SKEE	Gypsum			0.36	1.79	1.79
CPC-10SKEE	R2				0.98	1.25
CPC-10SKEE	37k				1.23	1.25
CPC-10SKEE	T14		0.31	2.00	3.74	3.74
CP7N__CARI	37k			0.69	2.02	2.02
CP7N__CARI	R6				0.98	1.25
CP7N__CARI	R2			0.43	1.76	1.76
GA-6__SKEE	37k			0.27	1.79	1.79
GA-6__SKEE	Gypsum			0.44	1.78	1.78
GA-6__SKEE	Barite			0.28	0.99	1.53
GA-5__SKEE	Barite			0.40	0.98	1.78
GA-5__SKEE	Gypsum			0.52	2.04	2.04
CPC-6_SKEE	T3			0.57	2.52	2.52
CPC-6_SKEE	37k				1.26	1.26
CPC-6_SKEE	R6			0.36	0.99	1.26
CPC-6_SKEE	R2				1.26	1.26
CPC-31SKEE	T14		0.28	1.24	3.02	3.02
CPC-34SKEE	37k				0.99	1.53
CPC-34SKEE	R2				1.53	1.53
CPC-30SKEE	T9a			0.26	1.51	1.51
CPC-30SKEE	S2B				0.98	1.25
CPC-28SKEE	37k			0.27	1.23	1.76
CPC-27SKEE	37k				0.98	1.51
CPC-27SKEE	T11			0.36	2.27	2.28
CPC-27SKEE	T9a				1.48	1.48
CPC-27SKEE	T9				1.23	1.50
CPC-27SKEE	N9				0.96	1.23
CPC-23SKEE	R2			0.27	1.25	1.25
CPC-23SKEE	37k			0.33	1.48	1.48
CPC-23SKEE	R6			0.70	1.51	1.51
CPC-21SKEE	T3		0.28	0.82	1.76	1.76
CPC-21SKEE	R6			0.31	1.00	1.27
CPC-21SKEE	R2				1.53	1.53
CPC-21SKEE	37k				1.26	1.26
CPC-20SKEE	N10		0.25	0.43	1.46	1.72
CPC-20SKEE	T9a			0.56	2.26	2.26

CPC-20SKEE	T9			0.74	1.96	1.96
CPC-17SKEE	R2			0.63	1.25	1.25
CPC-17SKEE	37k			0.36	1.25	1.25
CPC-17SKEE	R6				1.25	1.25
CPC-15SKEE	T3			0.65	2.22	2.22
CPC-15SKEE	37k			0.42	2.03	2.03
CPC-12SKEE	Gypsum			0.26	1.46	1.48
CPC-11SKEE	37k			0.37	1.25	1.25
CPC-11SKEE	T3			0.73	1.48	1.75
CPC-11SKEE	Gypsum			0.53	1.72	1.72
CP2___SKEE	37k			0.44	1.99	1.99
CP1___SKEE	N9			0.26	1.77	1.77
CP1___SKEE	T3			0.80	2.00	2.00
CNC-7_SKEE	T9a			0.93	2.72	2.72
CNC-4_SKEE	37k			0.79	1.74	1.74
CNC-4_SKEE	T9a			0.49	1.69	1.69
CNC-5_SKEE	T3			0.67	1.47	1.47
CNC-5_SKEE	37k			0.37	1.25	1.25
CNC-2_SKEE	37k			0.28	2.02	2.02
CNC-2_SKEE	R6			0.25	1.93	2.00
CNC-2_SKEE	R2				2.02	2.02
CNC-2_SKEE	Gypsum			0.27	2.48	2.54
CNC-2_SKEE	Barite			0.30	2.02	2.02
NP1C__CARI	Peridot			0.47	1.24	1.24
NP1C__CARI	Basalt		0.28	1.45	2.25	2.25
NP1C__CARI	F8b			0.34	0.98	1.25
NP1C__CARI	D6			0.28	1.77	1.77
CNC-6_SKEE	37k			0.78	2.76	2.76
CPC-29SKEE	N9			0.43	2.81	2.81
CPC-29SKEE	T9a			0.27	3.29	3.29
CPC-29SKEE	T9			1.20	2.27	2.27
CPC-29SKEE	37k			0.70	3.05	3.05
CPC-35SKEE	N9			0.39	3.07	3.07
CPC-35SKEE	T9a			0.55	2.49	2.49
CPC-35SKEE	R6			0.49	1.47	2.00
CPC-35SKEE	37k				2.56	2.56
CP13__SKEE	T3		0.27	0.57	1.75	1.75
CP13__SKEE	37k			0.40	1.49	1.49
CP13__SKEE	R2			0.26	1.76	1.76
CP13__SKEE	R6		0.25	0.61	1.98	1.98
CP15__SKEE	T3		0.30	0.66	2.49	2.49
CP15__SKEE	Gypsum				1.51	1.51
CP15__SKEE	Barite				1.25	1.25
CP15__SKEE	37k			0.35	1.25	1.25
CP16__SKEE	Gypsum				1.25	1.25
CP16__SKEE	T9a			0.27	2.02	2.02
CP16__SKEE	37k			0.52	1.74	1.76

CP6___SKEE	37k			0.41	1.22	2.03
CP6___SKEE	R2			0.54	2.03	2.03
CP6___SKEE	Feldspar			0.57	2.25	2.27
CP8___SKEE	R6			0.26	1.21	1.48
CP8___SKEE	Feldspar			0.57	3.06	3.06
CP8___SKEE	37k			0.46	2.28	2.28
CP8___SKEE	T3		0.29	0.65	2.76	2.76
CP9___SKEE	T3		0.31	0.77	2.23	2.23
CP9___SKEE	37k			0.53	2.77	2.77
CP9___SKEE	T9a				2.48	2.51
JB5___SKEE	Basalt		0.25	0.60	2.26	2.26
JH28__SKEE	Gypsum			0.29	2.05	2.05
JH28__SKEE	Barite			0.48	2.29	2.29
JH28__SKEE	N9			0.25	1.78	1.78
JH19__SKEE	Gypsum				2.57	2.57
JH19__SKEE	N9			0.35	2.54	2.54
JH19__SKEE	T9a			1.03	2.03	2.03
JH19__SKEE	B7				1.78	1.78
CP3___SKEE	N9				2.03	2.03
CP12__SKEE	O4			0.45	2.32	2.32
CP12__SKEE	37k			0.42	2.28	2.28
CP12__SKEE	T9a			0.45	2.80	2.80
CP12__SKEE	T9			1.23	2.53	2.53
CP12__SKEE	N9			0.28	2.02	2.02
1_____QCIS	D6			0.78	1.77	1.77
2_____QCIS	T11		0.28	2.10	4.61	4.61
KJ12__VANI	N9		0.27	0.56	2.80	2.80
KJ19__VANI	T14		0.27	1.92	2.53	2.53
KJ6___VANI	N10				1.28	1.28
KJ23__VANI	T14		0.30	0.72	2.27	2.27
S5____VANI	Barite				0.99	1.26
S5____VANI	T9a			0.28	1.22	1.49
S5____VANI	N9				2.01	2.01

Values shown are the weighted mean number of median size deposits that the expert panel estimated for the indicated deposit type and confidence level. These values were calculated by the RAW2MARK.exe program using the input shown in Appendix 5.

resultant estimates of commodity tonnages would be significantly different even though the estimated number of deposits in each of the tracts is virtually the same at each of the confidence levels. Also, for deposit models where each of the estimates at the 90, 50 and 10 confidence levels are 0.5 or less, all three values will be rounded down to 0 causing the simulator program to skip this deposit model entirely. To get around this problem the estimated number of deposits at the three confidence levels was multiplied by 10 prior to input into the Mark3B simulator program (Appendix 14). The predicted tonnes of commodity for the mean, 90, 50, 10, 5 and 1 percent confidence levels

Table 7. Commodity prices used to calculate GIPVs.

Commodity	Price USD$	Price basis	Units	CDN$/Tonne
ALUMINUM OXIDE	$0.62	Dec. 2002	LB	$2,136.74
ALUMINUM SILICATE	$149.00	Dec. 2002	TONNE	$232.06
ANDESITE	$216.00	Dec. 2002	TONNE	$336.41
ANTIMONY	$1.19	Dec. 2002	LB	$4,086.00
ASBESTOS	$206.00	Dec. 2002	TON	$315.77
BARITE	$25.00	Dec. 2002	TON	$38.32
CHROMITE	$65.00	Dec. 2002	TONNE	$101.23
CHROMIUM	$6,000.00	Dec. 2002	TONNE	$9,345.60
COBALT	$6.28	Dec. 2002	LB	$21,563.08
COPPER	$0.75	Dec. 2002	LB	$2,569.03
DIATOMITE	$256.00	Dec. 2002	TON	$392.41
FLAGSTONE	$623.00	Dec. 2002	TON	$954.98
FLOURINE	$143.00	10 yr average	TONNE	$222.72
GARNET	$50.00	Dec. 2002	TON	$76.64
GOLD	$317.00	Dec. 2002	TROY_OZ	$15,873,300.06
GRANITE	$262.00	Dec. 2002	TON	$401.61
GYPSUM	$8.46	Dec. 2002	TON	$12.97
IRIDIUM	$415.00	Dec. 2002	TROY_OZ	$20,780,503.23
IRON	$147.50	Dec. 2002	TON	$226.10
IRON ORE	$25.00	Dec. 2002	TONNE	$38.94
KAOLIN	$103.00	Dec. 2002	TON	$157.89
KYANITE	$149.00	Dec. 2002	TONNE	$232.06
LEAD	$0.22	Dec. 2002	LB	$741.32
LIMESTONE	$5.53	Dec. 2002	TONNE	$8.61
MANGANESE	$2.47	Dec. 2002	TONNE	$3.85
MARBLE	$312.00	Dec. 2002	TON	$478.25
MERCURY	$140.00	Dec. 2002	FLASK	$6,325.08
MOLYBDENUM	$3.40	Dec. 2002	LB	$7,780.91
NICKEL	$3.43	Dec. 2002	LB	$11,777.29
NIOBIUM	$6.25	Dec. 2002	LB	$15,010.02
PALLADIUM	$262.05	Dec. 2002	TROY_OZ	$13,121,761.13
PHOSPHOROUS	$25.00	10 yr average	TONNES	$38.94
PLATINUM	$587.50	Dec. 2002	TROY_OZ	$29,418,182.28
PLATINUM GROUP ELEMENTS	$11,100,000.00	10 yr average	TONNES	$17,287,806.00
QUARTZ	$19.50	Dec. 2002	TON	$29.89
RARE EARTH ELEMENTS	$8,813.00	10 yr average	TONNES	$13,725.90
RHODIUM	$1,800.00	Dec. 2002	TROY_OZ	$90,132,303.16
RUTHENIUM	$130.00	Dec. 2002	TROY_OZ	$6,509,555.23
SANDSTONE	$126.00	Dec. 2002	TON	$193.14
SHALE	$5.70	Dec. 2002	TON	$8.74
SILICA	$19.50	Dec. 2002	TON	$29.89
SILVER	$4.42	Dec. 2002	TROY_OZ	$221,324.88
TIN	$2.12	Dec. 2002	LB	$7,279.26
TUNGSTEN	$2.80	Dec. 2002	LB	$9,614.11

URANIUM	$9.90	Dec. 2002	LB	$28,825.86
URANIUM OXIDE	$9.90	Dec. 2002	LB	$33,992.75
WOLLASTONITE	$190.00	Dec. 2002	TONNE	$295.92
ZEOLITES	$70.00	Dec. 2002	TON	$107.30
ZEOLITES	$70.00	Dec. 2002	TON	$107.30
ZINC	$0.37	Dec. 2002	LB	$1,272.50
ZIRCONIUM	$23,000.00	Dec. 2002	TONNE	$35,821.58

were then divided by 10. This helped remove a large part of the variation caused by the program rounding down to a whole number of deposits prior to doing the simulation calculations and ensured that probabilistic estimates were made for all deposit models in all tracts or sub-tracts. The final data processing task for the metallic mineral deposit models was to determine the relative tract rankings using Gross-In-Place-Values (GIPV). This procedure for ranking metallic mineral tracts is the same as that used in the Level 1 MRA with the exception that the value of known resources was not included in the calculation. The Level 2 MRA rankings are based strictly on the predicted value of undiscovered resources determined by the Mark3B resource simulator as described above. To determine the Level 2 rankings the predicted tonnes of commodity for each deposit model in a tract at the various confidence levels was multiplied by the per tonne value in current Canadian dollars (Appendix 16). The values used for this calculation are listed in Table 7. The dollar values were then totaled for the tract and divided by the tract area to give a GIPV per hectare (Appendix 17). These values were then discounted by factors of 0.9, 0.5, 0.1, 0.05 and 0.01 for the 90, 50, 10, 5 and 1 percent confidence levels respectively. Finally, these discounted values were given an ordinal ranking from 1 to 226 for each of the confidence levels (Appendix 18). These ordinal ranks were then summed for each of the tracts or sub-tracts and this value was used to produce the final ordinal ranking for the tract. All of these calculations were done within an MS Access database. The final metallic mineral rankings are shown in Appendix 18. The rankings were then categorized into 5 divisions, each division representing 20% of the total project area. This classification is shown in Figure 5.

The ranking of tracts for industrial mineral potential does not use data from the Mark3 resource simulator. Instead a Relative Deposit Score Value (Table 8) is used as described for the Level 1 MRA. The number of predicted deposits is multiplied by the RDVS and then normalized to the tract area. These normalized values are discounted and ranked in the same way as the GIPV/HA values for metallic mineral deposits described above. The final rankings for industrial minerals are given in Appendix 19. The classified map based on 5 subdivisions each representing 20% of the total area is shown in Figure 6.

Known In-ground Resources

Unlike the Level 1 MRA, known in-ground resources (reserves) have not been included in the tract rankings. These values (Appendix 20) have been recalculated using current commodity prices and are presented as a point map (Figure 7) for use with the Level 2 MRA ranking maps.

Conclusions

The Level 2 MRA completed for the CIT project area is represents a significant improvement over the original Level 1 MRA because;

- In general tract (sub-tract) areas are smaller and more appropriate for land-use planning
- The subdivision of tracts into sub-tracts based on geology has resulted in a better definition of the potential within tracts to host specific types of deposits. This has resulted in a better definition of the areas within the CIT project area that have the highest mineral potential.
- Values used for ranking are based on current commodity prices
- Estimates for deposit models not included in the Level 1 MRA were added to the assessment and included in the final tract ranking.
- The final tract rankings for the Level 2 MRA are based on the potential for new discoveries only and are not influenced by known resources (in-ground reserves).
- Known resources have been re-valued using current commodity prices and presented as a separate map layer.

Table 8. Relative Deposit Value Scores (RDVS) for industrial mineral deposits in CIT project area.

Model Code	ModelName	RDVS
13i	U-Th Pegmatite	15
37k	Metamorphic Garnet	15
B6	Residual Kaolin	45
B7	Fireclay	40
Barite	Barite (Kuroko association)	30
Basalt	Columnar Basalt	15
C2	Paleoplacer (Garnet)	27.5
C3	Marine Placer	50
D6	Zeolites In Tuffs Of Open Hydrolic Systems	22.5
D7	Zeolites	22.5
E10	Sedimentary Kaolin	42.5
E10a	Sedimentary Kaolin	15
E6b	Carbonate hosted talc	50
E9	Bentonite	27.5
F4a	Bedded Gypsum/Anhydrite	20
F8b	Diatomite	25
Feldspar	Feldspar	15
Granite	Granite	15
Gypsum	Gypsum	35
I11	Hydrothermal Alteration Clays-Al-Si	50
K7	Silica Vein	60
N10	Wollastonite Skarn	50
N9	Garnet Skarn	15
P6	Ultramafic-hosted asbestos	95
Peridot	Peridote	10
Q1	Carbonatite-hosted deposits	87.5
R2	Kyanite Family	25
R4	Talc	50
R5	Microcrystalline Graphite	40
R6	Crystalline Flake Graphite	65
S1a	Opal	90
S2b	Rhodonite	55
T1	Cement Shale	15
T10	Pumice	40
T11	Perlite	22.5
T13	Alaskite	25
T14	Crushed Rock	15
T2	Expanding Shale	25
T3	Dimension Stone Granite	15
T4	Dimension Stone Marble	17.5
T5	Dimension Stone Andesite	15
T6	Dimension Stone Sandstone	50
T8	Flagstone	15
T9	Limestone/Dolostone	40
T9A	Limestone/Dolostone (WHITE)	25

❖

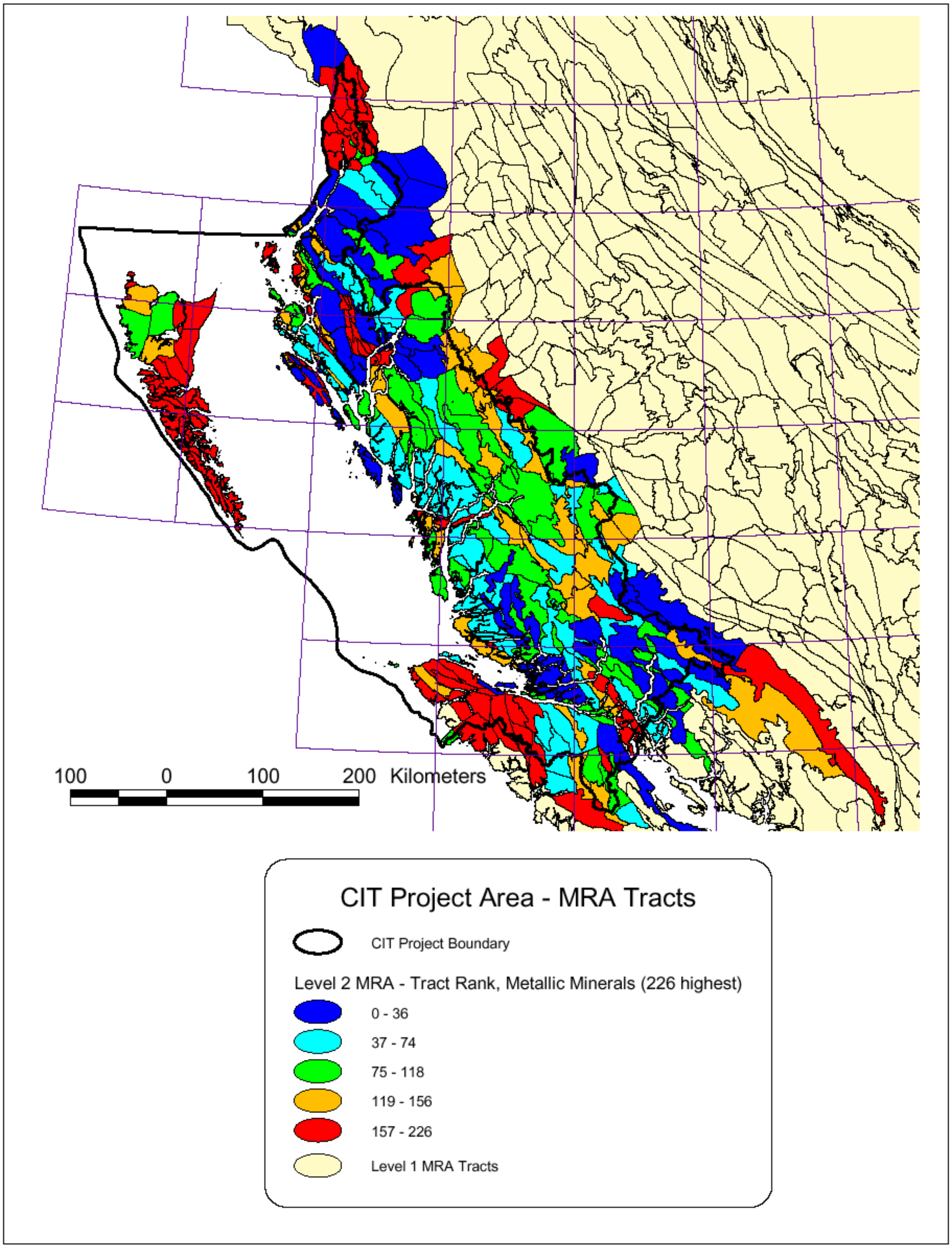

Figure 5. Tract rankings, Level 2 MRA, Metallic Mineral Deposits, CIT Project Area. Each category represents 20% of the total tract area (226 tracts).

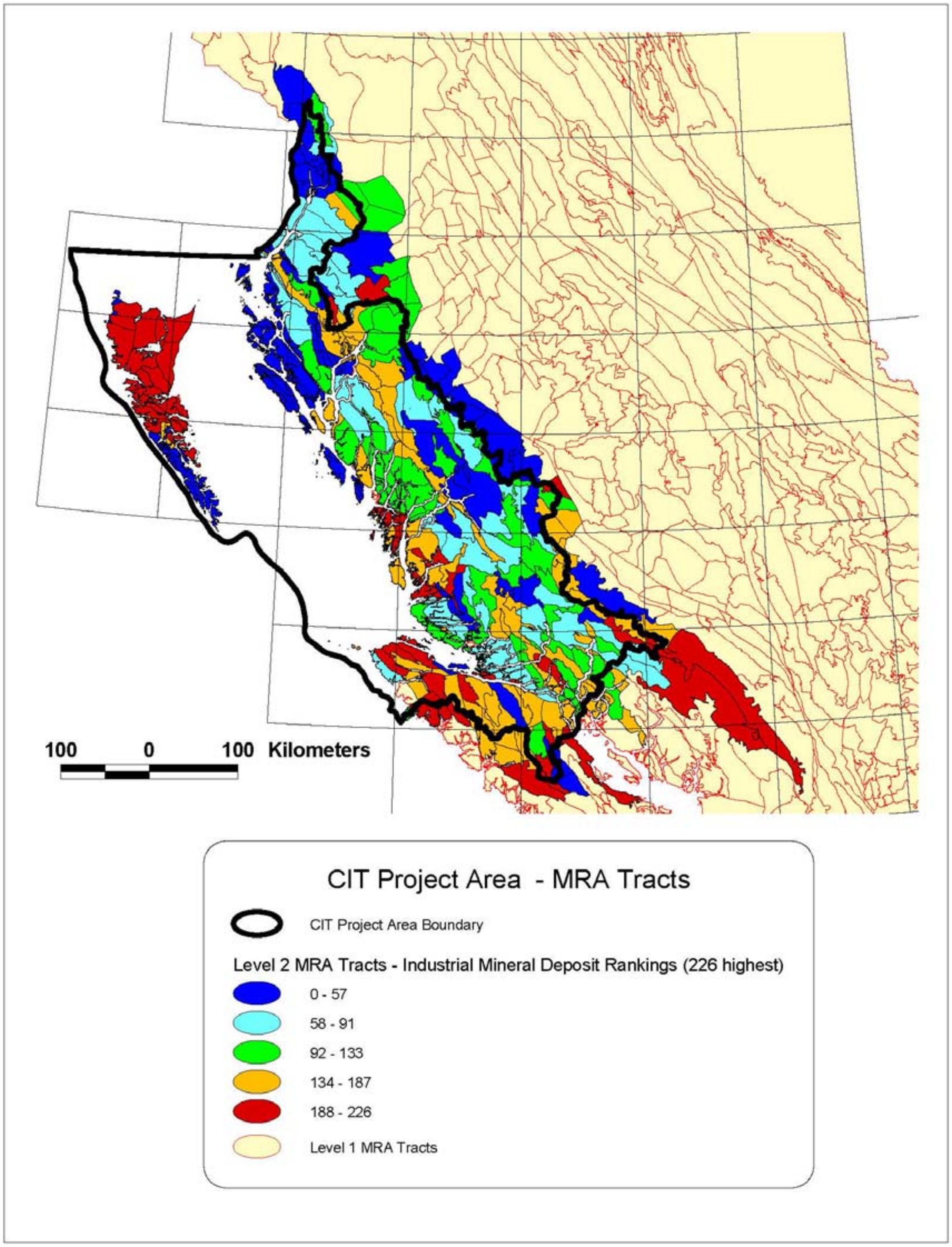

Figure 6. Tract rankings, level 2 MRA, Industrial Mineral Deposits, CIT Project Area. Each category represents 20% of the total tract area (226 tracts).

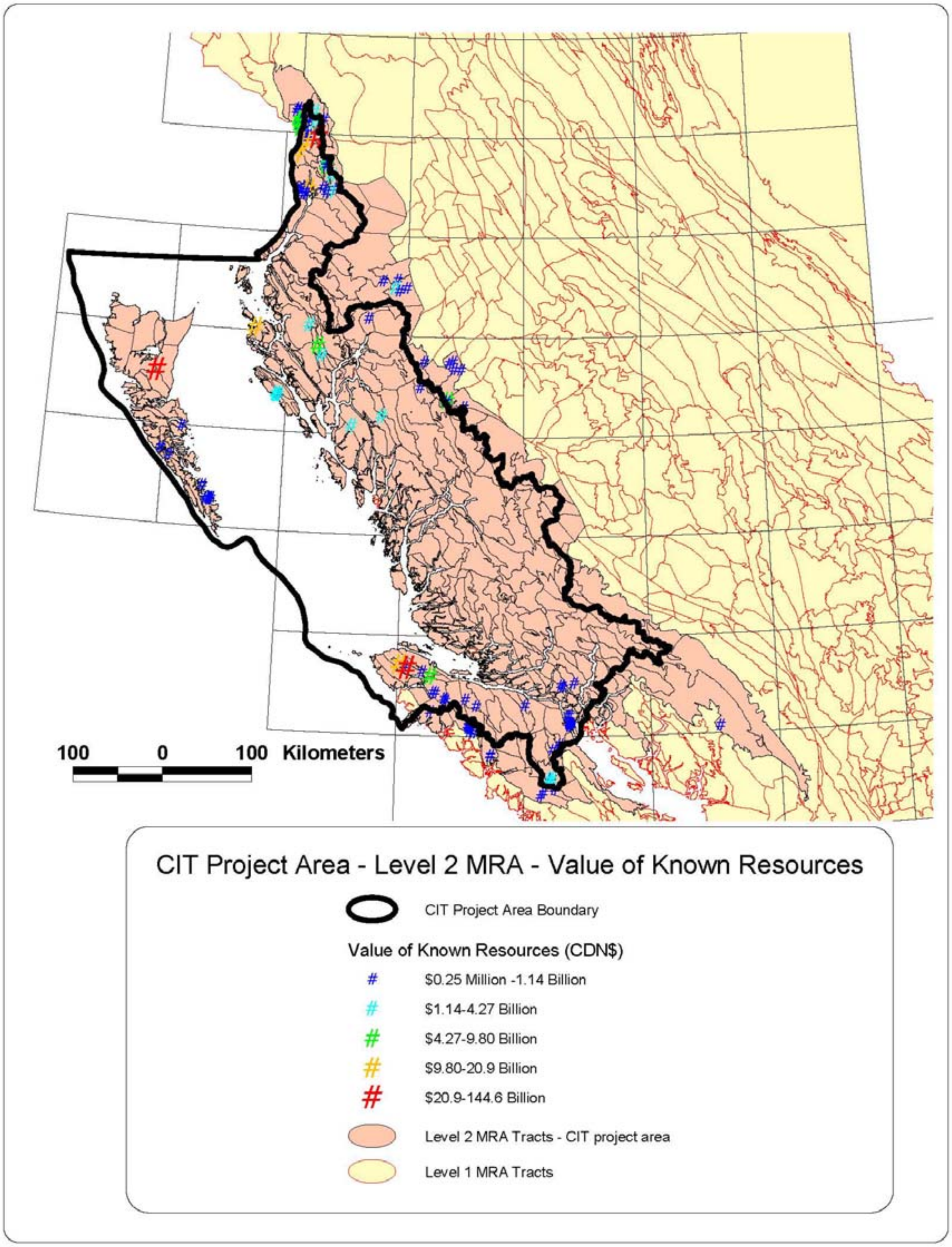

Figure 7. Value range of known mineral resources (reserves) in the CIT Project Area.

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